The dynamics between water asymmetry, inequality and heterogeneity sustaining canal institutions in the Makanya catchment, Tanzania

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Abstract

It has been suggested that the collective action needed for integrated water management at larger spatial scales could be more effective and sustainable if it were built, bottom-up, on the nested arrangements by which local communities have managed their water resources at homestead, plot, village and sub-catchment levels. The upscaling of such arrangements requires an understanding of why they emerge, how they function and how they are sustained. This paper presents a case study of local level water institutions in Bangalala village in the Makanya catchment, Tanzania. Unlike most research on collective action in which water asymmetry, inequality and heterogeneity are seen as risks to collective action, this study looked at how they dynamically interact and give rise to interdependencies between water users which facilitate coordination and collective action. The findings are confined to relatively small spatial and social scales, involving irrigators from one village. In such situations there may be inhibitions to unilateral action due to social and peer pressure. Spatial or social proximity may thus be a necessary condition for collective action in water asymmetrical situations to emerge. This points to the need for further research, namely to describe and analyse the dynamics engendered by water asymmetry, inequality and heterogeneity at larger spatial scales.

Keywords: Canal irrigation; Collective action; Common pool resources; Cooperation; Interdependence; Water allocation


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1. Introduction

Canal organisations in the Makanya catchment, Tanzania, have been managing the allocation of water for multiple uses between households for more than 50 years. Water is used for domestic purposes, construction (brick making), the watering of animals and for irrigation. The latter use will be the focus for this paper as it is the largest water consumer by far, and also because (in other canal systems reported in the literature) farmers have been able to negotiate water-sharing arrangements at plot, village and sub-catchment levels (see Fleuret, 1985; Wade, 1988; Ostrom, 1990, 1993; Grove, 1993; Adams et al., 1994, 1997), overcoming collective action problems related to water provisioning and allocation in many parts of a catchment. It has been suggested that understanding why these arrangements endure even in the face of access inequality could form the basis for integrated water management at larger spatial scales (Van der Zaag, 2007).

In this paper we propose that local water institutions can endure over time because three phenomena, namely water asymmetry, inequality and heterogeneity, dynamically interact and create interdependencies between water users that may foster coordination and collective action concerning a particular water resource. We provide theoretical arguments for this proposition and illustrate it with a case study. In the concluding section we show the relevance of this proposition for contemporary water resources management and formulate a research agenda. In this introduction we briefly summarise our proposition, focusing first on inequality, then on water asymmetry, and on heterogeneity.

The use by many appropriators of a common pool resource such as a fishery or a groundwater body (aquifer) requires coordination. It is widely accepted that coordinating many dispersed users poses a challenge and, in many instances, proves ineffective or impossible. It has been shown that inequality among appropriators, for example manifested by unequal amounts of the natural resource used, may sometimes lead to collective action. This is because the large resource users tend to be willing to contribute more to collective action, which may in specific cases be sufficient to allow some free-riding of small-scale users (see Olson, 1965; Baland & Platteau, 1999).

Water flowing through a river or a canal can also be understood as a common pool resource. However, in such a case there is an additional complication, namely that surface water normally flows in one direction only. This unidirectional effect creates an asymmetrical situation: the action of upstream appropriators to use or refrain to use water influences the ability of downstream users to do the same, but not vice versa. This water asymmetry adds a new dimension to the coordination problem, as upstream users are not interested in collaborating.

Here, collective action and coordination is less self-evident than in more symmetrical common pool resources such as fisheries or aquifers. Situations where, in the absence of a regulatory authority, such coordination nevertheless occurs thus merit careful analysis. We hypothesise that inequality will not be a sufficient factor to induce coordination in the case of flowing water, but that the interdependence of the resource users may be an additional requirement, and that interdependence is likely to arise out of the differences, other than inequality, between the resource users. This diversity we denote as heterogeneity.

Heterogeneity is thus defined here as the diversity in character or content of a particular entity among a group of users. Heterogeneity can arise from differences in soil types, differences in (micro) climate, differences in crops grown, irrigators having plots in different parts of the command area, socio-cultural differences and kinship relationships between irrigators in different locations of the command area. Such heterogeneities may create interdependencies among users because individual users specialise, e.g. in producing certain crops, which may be bartered with other irrigators producing different crops, or...
because irrigators may have multiple loyalties. Interdependence is defined as a situation where two or more people depend on each other in more than one way; it highlights the hydrological, social and economic feedbacks of actions or inactions of users in a canal or catchment. Interdependence is here considered to be an emergent property of heterogeneity.

Thus, while water asymmetry may impede coordination or cooperation over the allocation of water resources, this might be counterbalanced by: (i) the interdependencies arising out of heterogeneity within the user group; and (ii) inequality in terms of land or water use, which may allow large users to invest more than proportionally in coordination efforts. In such a water system where water flows from upstream to downstream, this dynamic interaction may influence and reconfigure power relations. The status quo can be interpreted as being the outcome of a delicate balance that is constantly being challenged and has to be re-enacted continuously; and in this process water institutions evolve and endure.

A typical example where inequality, asymmetry and heterogeneity coalesce is the case of canal maintenance in many farmer-initiated irrigation canal systems, as reported, for example, by Martin & Yoder (1988), Boelens & Davila (1998) and Manzungu et al. (1999). Interdependence between water users may arise when labour requirements for canal repairs is high. This often occurs in the head end of an open canal system (at a river diversion, intake works, or the first stretches of canal that may cut through rough terrain before reaching the command area), and in such cases the irrigators in the head end, although in an advantageous hydraulic position, depend on the cooperation of their tail-end counterparts. Seasonal work parties are sometimes ritualised and may reconfirm the membership of the common canal and the claim to water for all. This composite of factors appears to sustain such systems despite a clear water asymmetry and marked differences between irrigators.

The remainder of this paper is organised as follows. Section 2 provides a theoretical review of the concepts of water asymmetry, inequality and heterogeneity. Section 3 describes the research methods and the case study catchment. Focusing on one sub-catchment of Makanya, Section 4 presents water-sharing arrangements: (a) in one farmer-built and operated irrigation canal, locally known as a furrow (‘mfereji’); and (b) between furrows in one village. Section 5 discusses the initial proposition in light of the research findings and formulates an agenda for further research.

2. Conceptual review: inequality, water asymmetry and heterogeneity

Substantial research has been carried on the management of common pool resources and it is now widely accepted that local communities do self-organise to overcome management challenges related to resource use (see Wade, 1988; Ostrom, 1990; Baland & Platteau, 1996). However, there is a lack of conceptual clarity on how collective action emerges and is sustained in settings where water asymmetries exist, namely in cases where different users depend on water flowing along a canal or river.

Water asymmetry arising out of the unidirectional flow of river or irrigation water adds to the coordination challenge over common pool resources. In a study of river committees in the Themi sub-catchment, Tanzania, Komakech & Van der Zaag (2011) found that water asymmetry negatively impacts on collective action and the river committees’ effectiveness. It may also increase the level of inequality, as larger land owners are more likely to occupy land in the head end of an irrigation command area. However, a certain level of inequality in the capacity to access and appropriate a resource may promote collective action. Individuals with higher endowments are in some circumstances more
willing to meet the costs of initiating collective action as long as they reap higher benefits from the resource (Baland & Platteau, 1999). In a study of agricultural cooperatives in Ecuador, Jones (2004) found that wealthy individuals were more likely to take the entrepreneurial role and initiate collective actions. But he also cautioned that such inequality and exclusive trust may later negatively affect the success of cooperation because of increased free-riding on the wealthy (Jones, 2004). Other studies, however, have found that inequality may in fact be a deterrent to cooperation (Varughese & Ostrom, 2001), as it leads to unequal sharing of decision-making rights, a low level of trust and unequal allocation of benefits (Bardhan & Dayton-Johnson, 2002). Bardhan (2000) found that landholding inequality correlates negatively with maintenance of irrigation canals. He argued that a more egalitarian agrarian society would be more likely to solve collective action problems related to irrigation management. Molinas (1998) posited a nonlinear relationship between inequality and collective action: very low and high levels of inequalities impede collective action, and medium levels are likely to enhance collective action. Through large-scale studies of irrigation systems in India and Mexico, Bardhan & Dayton-Johnson (2002) concluded that wealth inequality has a U-shaped relationship with collective action. Low inequality implies that few people have the capacity or can afford to meet the cost of initiating collective action while high levels of inequality may generate resentments (Andersson & Agrawal, 2011).

It is evident that there is no consensus in the literature with respect to the relationship between inequality in a resource endowment and collective action. This may be explained because different types of natural resources have been expected to behave similarly, while they do not. We propose that it is useful to distinguish common pool resources with respect to their symmetry, and that fisheries and groundwater fundamentally differ in this respect from water flowing through a canal or river: the effect of one unit appropriated by one fisherperson or groundwater user is the same for all other appropriators and does not depend on their wealth or size or position; for appropriators of flowing water, their impact on other users does depend on their position (whether they are located upstream or downstream). This therefore generates different conditions for collective action.

The question, then, is why does collective action nevertheless emerge among unequal water users? Our hypothesis is that water asymmetry can at least partly be overcome by interdependence, and that interdependence can emerge out of heterogeneity.

Heterogeneity is not well described in the literature on common pool resources and collective action. In many cases heterogeneity is conflated with inequality. This, in our view, is problematic: whereas heterogeneity can be understood as ‘not being of the same type’, i.e. being different (and measured at different metrics), inequality means scoring differently in the same metric. We argue that distinguishing between inequality and heterogeneity may provide conceptual clarity and yield a better understanding of their linkages.

In the literature, some attention has been paid to political heterogeneity, socio-cultural differences and kinship relations. Political heterogeneity relates to the agreement about who is responsible for creating, maintaining and enforcing rights and rules for the use of common pool resources (Vedeld, 2000). This dimension is about the leadership roles and authority of individual users in decision-making positions and their legitimacy. Economic elites are more likely to bear the cost of initiating and performing regulatory tasks than others because they are likely to benefit both socially and materially from collective action (Baland & Platteau, 1996, as cited in Vedeld, 2000; Jones, 2004).

According to Adhikari & Lovett (2006), ethnic heterogeneity is likely to increase the cost of collective action, because of the need to reconcile a diversity of values among different groupings. Another dimension of socio-cultural heterogeneity is gender. Women’s exclusion in decision making may
negatively affect collective action (Meinzen-Dick & Zwartteveen, 1998; Agrawal, 2001), and there is some evidence that increased female representation in decision making improves the performance of collective action institutions, for example in domestic water supply (Adhikari & Lovett, 2006). More importantly, a higher level of female participation does not necessarily mean that the benefits are shared more equitably. Women often get fewer benefits from collective activities than men do.

The literature thus provides some interesting contributions to what could be called ‘socially constructed heterogeneity’, including political, ethnic and gender heterogeneity. Another type is biophysically induced heterogeneity, which in canal and river systems is primarily linked to landscape features, geology and climate; here diversity is associated with different positions in this landscape. The upper parts may typically have soils derived from parent material (bedrock) with low water-holding capacity and a wetter (e.g. sub-humid) climate, whereas the lower parts may have alluvial soils and a dryer (e.g. semi-arid) climate. This biophysical heterogeneity creates different ecological niches in different parts of the command or catchment area, resulting in the production of different environmental goods and services, and conditions the opportunities to produce different crops in different places (for a discussion of farming systems research, see Ruthenberg, 1980).

Lansing & Miller (2005) described the role of biophysical interdependencies in promoting cooperative practices among Balinese rice farmers in Indonesia. They observed and explain, using a model based on game-theory that the selfish behaviour of upstream farmers with respect to water use is mitigated by the threat of crop pests. In the catchment downstream, farmers are more concerned with water shortages while those upstream are concerned about the threat of pests. Without coordinated cropping patterns (e.g. having an identical fallow period) and fair water sharing, everyone is left worse off. It is the realisation of the need for coordination, as dictated by ecological linkages, that sustains the farming system (Lansing & Miller, 2005).

In this paper we explore how heterogeneity and inequality play out empirically in situations with unidirectional flows of water. We analyse the canal institutions in the small Makanya catchment area, Tanzania, with the aim of sharpening our understanding of the emergence of enduring water institutions.

3. Research methods and case study

3.1. Research methods

The research strategy was inspired by the ‘follow the water’ approach (Latour, 1988, 2005; Law, 1992; Murdoch, 1998; Kortelainen, 1999; Bolding, 2004). To identify water users and their networks, we followed the water and, in the process, mapped all infrastructures and institutions around it. Fieldwork was undertaken between July 2007 and August 2008 with subsequent visits in 2009. The methods used included mapping, field observation and semi-structured interviews.

We first mapped all six irrigation canals in Bangalala village that rely on water from the Vudee river, using a GPS. Field observation and interviews provided first-hand accounts of irrigation practices. We observed that many farmers had plots along more than one irrigation canal. We then focused on two irrigation canals located on either side of the Vudee river. For these canals we generated a detailed land ownership map. To do this we worked with the elected branch canal (or irrigation zone) representatives, who assisted with mapping the irrigation canals and identifying the owners of the irrigated plots. The land mapping provided us with the opportunity to trace kinship (actors’ clans, inter-marriages, etc.).
We also observed variations in soil characteristics, notably differences in the water-holding capacity of soils found in the command area (upstream and downstream).

Next we focused on one of the two irrigation canals, the Mkanyeni canal, and interviewed 31 out of the 83 active members (age 18–79 years; 20 male and 11 female). We collected: historical narratives on the irrigation canal construction; dates for when a farmer joined the water using group and why; land ownership details; crops normally grown; current water allocation rules; details of water variability and how this affects the member’s participation; and details of membership of other groups. The interviews made it possible to trace the development of the irrigation infrastructure over time, to see who the founders were, how ownership and membership are defined and how the system is being maintained. During the interviews with farmers, land ownership within the command area of an irrigation canal emerged as a precondition for membership in a particular irrigation group. Membership gives a farmer access to canal water for irrigating crops, but the use of canal water for drinking, washing and for livestock is allowed for all inhabitants of the village. Using the map, we obtained information on kinship and membership of clans and were able to relate this to land ownership. This was done by presenting our detailed land map to the farmers at the irrigation groups’ weekly meetings, asking them to clarify the names, and to add information on clans and other related attributes to the map.

We observed weekly water allocation meetings and general elections of new water committees, which provided first-hand observations of the dynamics of water allocation but also created opportunities to interview more farmers. We observed that women members complain bitterly about unfair treatment with respect to water allocation. We later interviewed some female farmers and learned that many of them resort to other means to access irrigation water: they may borrow water from the allocation of a relative or connive with branch canal representatives to open the storage dam (‘Ndiva’) and use the night storage to irrigate at night, often leading to conflict with the farmers scheduled to irrigate the next day.

The irrigation infrastructure was recently improved by nongovernmental organisations (NGOs) working on food security and value addition. The Same Agricultural Improvement Project (SAIPRO) Trust and Vredeseilanden Country Office (VECO) contributed towards the rehabilitation of the irrigation canals, but also set new conditions of membership and ownership for them. We interviewed the director of SAIPRO about NGO work in the area. We also consulted secondary materials, such as records of attendance at routine maintenance events and the water allocation diaries kept by the irrigation zone representatives. The latter provided information on the number of farmers requesting water, allocated water and the number that actually irrigated. During the research period, translation from Swahili to English and vice versa was undertaken by a native speaker.

3.2. Biophysical and socio-economic context

Makanya catchment (300 km²) is located in the south Pare Mountains in the mid-reaches of the Pangani river basin in eastern Tanzania (Figure 1). It lies between latitudes 4°15′ to 4°21′ S and longitudes 37°48′ to 37°53′ E, with altitude ranging substantially from 500 to 2,000 m.

The catchment represents typical semi-arid to dry sub-humid rain-fed agrarian conditions, and manifests strong signs of human-induced land degradation caused by high pressures on soil and water resources (Enfors & Gordon, 2007). Rainfall distribution in the catchment is bimodal (i.e. with a short and a long rainy season). The short season (locally called ‘Vuli’) occurs between October and December, whilst the long season (locally called ‘Masika’) is between March and May. However, in
some years, the ‘short’ season lasts longer than the ‘long’ season. Precipitation varies: in the highlands, with 100–500 mm/season and 200–800 mm/season during Masika and Vuli, respectively; in the midlands, between 0–400 mm/season and 50–800 mm/season during Masika and Vuli, respectively; and, in the lowlands, rainfall drops to between 50–300 mm/season and 0–100 mm/season during Masika and Vuli, respectively.
The catchment is drained by the Makanya river, starting from the Shengena Mountain (with a peak at 2,001 m above sea level). The river is reported to have been perennial up to the 1970s but has become ephemeral and only reaches the Pangani river during flood events (Mul et al., 2011). Farmers have constructed several furrows across the catchment. In the highlands, apart from domestic and livestock uses, the river water is diverted for dry season irrigation. In the midlands it is used for supplementary irrigation during both rainy seasons, while in the lowlands flash floods are used for spate irrigation during and immediately after flood events (Komakech et al., 2011). To boost flow into the furrows, highlands and midlands farmers use micro-dams (locally called ‘Ndivas’) to store water at night. Currently over 75 such storage infrastructures exist in the catchment (Mul et al., 2011). Furrow water serves multiple purposes: as well as being used for (supplementary) irrigation, it is also used to meet domestic, livestock, building material and tree nursery water demands. Water-sharing practices have emerged to resolve water scarcity-induced conflict in the different parts of the catchment. One such arrangement exists between farmers in the villages of Bangalala, Vudee and Ndolwa located in the Vudee sub-catchment (Mul et al., 2011). Bangalala is in the lowlands, while Vudee and Ndolwa are in the upstream part of the sub-catchment.

This case study analyses the nested water-sharing practices that have emerged between farmers in Bangalala village on two scales. In 2008, the population of Bangalala was estimated to be 3,800 (Same District, 2008). Bangalala farmers use Vudee water for irrigation and have developed six irrigation canals. The farmers practice supplementary irrigation during the rain seasons (Masika and Vuli) and full irrigation in the dry period (June–September and January–February). Water shortages are severe in the period July–October and the goal of most farmers is to secure long-term access to water for irrigation, domestic and livestock needs. In the next section we first describe the water-sharing arrangements within one irrigation canal (Mkanyeni) and then the arrangements between canals in one village (Bangalala).

4. Water-sharing arrangements

4.1. Evolution of water-sharing practices in Mkanyeni furrow

The Mkanyeni furrow (Figure 2) has a command area of about 94.8 ha, and consists of 1.6 km of primary canal, a micro-dam (storage capacity of approximately 1,015 m³), and two major secondary canals. The canals are unlined, while the intake is made from stones, twigs and mud (it leaks and regularly gets destroyed by floods). Significant labour efforts are required to sustain the furrow system. The intake capacity is not fixed (in May 2008 the average flow in the main canal at the intake fluctuated between 40 and 56 l/s). The secondary canals form a canal network of about 9 km serving three irrigation zones, each having a name (Dido, Ijeta and Itongoye vivi; see Figure 2). Itongoye vivi is upstream and, during low flows, water allocation is restricted to this zone. Ijeta and Dido are in the flood plain and the soils have a higher water-holding capacity compared to soils in the upstream areas. In 2008 there were 83 members (membership has varied in the past, being 90 in 2006 and 79 in 2007). Farmers can leave the group as and when they deem fit but they are reportedly charged a fee to re-join of 10,000 Tanzania shillings (Tsh.) (equivalent to 8.40 USD at the time of fieldwork in 2008).

It is not clear when the furrow (‘mfereji’) was constructed, but farmers interviewed say the Kitojo and Safieli Chungankwi families constructed it in about the early 1940s. When other families whose plots
could be irrigated requested to join, they were allowed to become members. New entrants would provide a kilo of sugar or 5 litres of local alcoholic brew as an entry fee to the leaders of the furrow founding families and had to commit to participate in the maintenance of the canal. From 2001, new members have paid a one-off membership fee (called ‘Ukarabati’, which is also translated as a rehabilitation
fee) of Tsh. 500 (0.42 USD), and a registration fee (called ‘Kiiingilio’, translated as ‘entrance’) of Tsh. 500 (0.42 USD). The membership fee is meant as a contribution towards the prior investments made by the group.

To capture night flows and avoid irrigating at night, the families constructed a micro-dam using stones and clay in about 1949. In 1952, the management of the furrow system was given to Lungiro Kitojo, the son of Kitojo, while Saffieli Chungankwi constructed another micro-dam downstream (according to farmers interviewed, Chungankwi was a famous mason in the village and considered very innovative). Lungiro allowed more people to join but his descendants later wanted to regain complete control of the furrow system, claiming it was their inheritance. The village elders, however, advised them to share the furrows with the other members since they contributed to maintaining it. Descendants of the founding families still have a location advantage, i.e. they own plots in the upstream parts of the command area, and they also own the biggest plots in the irrigation zones. In the 1970s, the government abolished natural resources management by clanship; as a consequence the irrigation system was declared village property but they continued to be managed by the founding families. By 1978, membership had increased beyond the capacity of the system, so the group decided to enlarge the micro-dam in order to address the increase in water demand and store more water for its members. They also lined it using cement to reduce water leakage. By 1999, the micro-dam was again leaking and the group sought assistance from non-governmental organisations and CARITAS (an international NGO working in Same District) provided cement and food for work during construction, whilst VECO (another international NGO working in Same District) provided a bulldozer for the micro-dam expansion. In 2002, the Ndiva ya Mkanyeni (abbreviated to Ndimka) water user group was formally established.

In 2003, the micro-dam again started leaking and the farmers sought assistance from SAIPRO. SAIPRO agreed to provide resources for its reconstruction but on condition that the farmers create and adopt a written constitution, that they pay a so-called ‘commitment fee’ of Tsh. 5,000 (4.20 USD) each to SAIPRO, and that they all contribute by gathering stones, paying for the mason, pipes and gate valve. To meet this latter requirement a seasonal fee (called ‘Ada’) of 1,000 Tsh. (0.84 USD) was introduced. In 2007, the Ndimka group started the process of developing a written constitution (‘Katiba ya Ndimka’). The constitution, which defines roles and responsibilities of members and sanctions, includes old and new rules. Box 1 gives an extract of principles from the draft constitution. Note that, in the draft constitution, some of the old norms and traditions have been changed in terms of gender roles, age and membership. For instance, membership and registration fees were increased, a new rule acquitting older members from maintenance activities was introduced, and anyone with access to land could become a member and a leader (this rule allows female members the opportunity to become leaders, something that was not allowed in the past). Money collected by the irrigation group is used to procure materials such as cement, tools (e.g. spades) and for paying masons during repairs of the Ndiva.

4.2. Furrow management and sustainability

Although all furrows were declared village government property in the 1970s, their management has remained outside local government structures. Instead of the founding families providing leadership, a periodically elected water committee is now in charge of Mkanyeni. The committee is responsible for water allocation, conflict resolution, supervision of maintenance activities, monitoring compliance,
calling for meetings and negotiating water-sharing arrangements with the other furrow groups in Bangalala village, as well as in the other upstream villages. The committee is comprised of a chairperson, vice chairperson, secretary (who also doubles as a treasurer), four elders (‘Wazee Washauri’, translated as council of ‘wise’ elders), and three irrigation zone representatives (‘Halmashauri’). Since 2001, elections for the committee have been held every 3 years. The election process is supervised by the village government, and this is the only major role the village government has in furrow management. We witnessed the elections of Mkanyeni and Manoo water committees in April and May 2007, respectively.

The positions of chairperson, secretary and irrigation zone representatives are elected by secret voting (using a ballot box), while that of the elders is by consensus. The position of vice chairperson is filled by the runner up for the chairperson position. However, for both Manoo and Mkanyeni, 1 week before the election day, the outgoing chairperson and his committee nominated three persons whom they considered fit to fill the chairperson position. If the sitting chairperson is still interested, his/her name could have been included (this was the case for Mkanyeni and the sitting chairperson indeed got re-elected). The names of these individuals were floated to the members for election and members voted secretly under the supervision of the village government representative. For the zone representatives (‘Halmashauri’), names were proposed by farmers from the respective zones and votes cast to elect the representative for each canal. For the elders (the Wazee Washauri), four individuals were also nominated by the farmers. Each irrigation zone nominated and elected their elder, and the presiding officer from the village government conducted the vote once the farmers present at the election had nominated the candidates. The criteria for nomination of the elders were that all three zones must be represented and that at least one of the elders must be female. The elected committee then elected the secretary/treasurer.

Box 1. Extracts from Ndimka draft constitution. (Source: translated from Swahili to English by the authors).

- Anyone above 18 years of age who lives in the village and owns a plot within the command area can be a member.
- All new members pay an entry fee of Tsh. 1,000 and a registration fee of Tsh. 5,000 but members with salaried jobs pay Tsh. 2,000 as an entry fee.
- All farmers pay a seasonal (per half year) fee of Tsh. 1,000.
- Members who are 70 years of age or older are excused from working; disabled persons pay a nominal fee.
- Members in formal employment, such as teachers and other government employees, are excused from maintenance activities but must contribute Tsh. 10,000 yearly.
- Not participating in maintenance activities, delay in paying seasonal fees or missing meetings attracts a penalty of Tsh. 2,000 and defaulters must still do the work after paying.
- Any member caught stealing water will pay Tsh. 10,000, and is given a warning. If caught three times, he or she will be dismissed from the group. Non-members caught stealing water are to be sued through the formal legal procedures.
- Bathing, washing clothes and watering animals inside the canal is prohibited, and a fine of Tsh. 10,000 applies, because it pollutes and damages the canal banks.
Although we witnessed that the election process was transparent and fair, through spatial mapping of the furrow system we found that the elected individuals or their relatives tend to have access to the largest irrigated area. In addition, those elected for the chairpersons’ positions were all descendants of the irrigation canal founding families. By preselecting the candidates for chairperson, the founding families continue to maintain some control over the furrow system. Farmers with many plots frequently lend some of their plots to friends, which may increase their chances of being selected as leaders.

4.3. Land access inequality and heterogeneity

We mapped all the plots within the irrigation area and found that 132 farmers (37 of them female) have plots in the command area, with average land access of 0.69 ha. Only 79 (27 female) of the plot owners are currently active member of the irrigation group. Four of the active member borrowed their land. Figure 3 shows that the top 20% of farmers (in terms of largest land access) own 50% of the irrigation area and that the bottom 50% of farmers (in terms of smallest land access) control about 20% of the land area. In addition to having land in all three irrigation zones, farmers belonging to the founding clans (Mmbaga and Mshana) also control the largest land area in the Mkanyeni system (Table 1). The Gini coefficient of land access in Mkanyeni is 0.58\(^1\). Moreover, nearly half of all farmers (49%, 65 out of 132) own at least two plots in the command area and one-third (46 out of 132) have plots in at least two zones. The latter fact evens out, to some extent, the impact of upstream priority allocation during periods of water shortage.

Furthermore, the location advantage enjoyed by upstream farmers (Makurira et al., 2007; Kemerink et al., 2009) seems to have little impact on crop yields. This is true for both Mkanyeni and Manoo furrows. In semi-arid areas where water is a limiting factor, the water-holding capacity of the soil plays a significant role. Bangalala furrow system farmers all have their downstream plots located in the flood plain where weathered alluvial materials are deposited (Mul et al., 2007). Downstream plots therefore have soils with higher water-holding capacity compared with upstream plots. The farmers are aware of this added advantage and during interviews they reported that one irrigation turn or water allocation to plots in the downstream area is sometimes sufficient to obtain a good harvest.

4.4. Furrow water allocation, conflict and gender

The Ndimka water committee meets every Thursday, normally at 2 pm, with the group members deciding on the water allocation for the coming week, discussing maintenance issues, and to solve conflict, among others. Although Ndimka’s draft constitution requires all members to attend, only farmers needing water are normally present. As further described below, Mkanyeni furrow gets water for 3 or 4 days per week. Within the furrow, water is first allocated to the irrigation zones (Dido, Ijeta and Itongoye vivi) and then to the farmers in each zone. Water allocation between the irrigation zones within Mkanyeni furrow is made in turns: each zone gets a 1 day allocation per week, except in the week that Mkanyeni takes river water for 4 days, in which case one of the zones is allocated

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\(^1\) The Gini coefficient is calculated as the ratio of the area between the line of equality and the Lorenz curve (the line of cumulative land share in Figure 3) and the total triangular area under the line of equality.
Fig. 3. Unequal land access in Mkanyeni furrow system. In terms of irrigated land access, the top 20% of farmers own 50% of the irrigated land, whilst the bottom 50% of farmers control only 20% of the irrigation land area (Source: field mapping).

Table 1. Land access distribution by clan in the three zones of Mkanyeni furrow.

<table>
<thead>
<tr>
<th>Clan</th>
<th>Dido (%)</th>
<th>Ijeta (%)</th>
<th>Itongoye (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area: 38.6 ha</td>
<td>Area: 27.5 ha</td>
<td>Area: 28.7 ha</td>
<td>Area: 94.8 ha</td>
</tr>
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<td>0.5</td>
<td>0.2</td>
<td>0.4</td>
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2 days; this additional day is rotated amongst the zones every time it occurs. To minimise losses during extreme shortages, water can be allocated to the upstream zone only. Itongoye vivi (located nearest to the micro-dam) was observed to receive more irrigation turns during the dry season than the other zones.

Unlike water allocation between the zones, which is directed by the group’s chairperson, water allocation to individual farmers is conducted with direct assistance from zone representatives and the council of elders (‘Wazee Washauri’). Water allocation to a farmer depends on the zone, water availability, the state of the crop and the condition of the distribution canal. Allocation is per farmer and not time-based. Farmers with plots in more than one zone are allowed to irrigate only one plot when there is insufficient water. On average, three farmers per day can be allocated water in the system and some of the water allocation criteria include: whether the farmer prepared the canal section leading to the plot, participated in routine work, or paid the membership fees. It is the responsibility of the zone representative to ensure that farmers in his/her zone fulfill these conditions. However, they do not rigidly adhere to the requirements; there are situations where the canals are cleaned after allocation has been made.

When the river carries sufficient water, allocation usually starts with downstream zones or plots, moving upstream, but during periods of low flow, water allocation starts upstream. Sometimes the furrow committee anticipates excess flow (referred to as ‘mafuriko’, the Swahili for flood) and allocate water to six or seven farmers (more than the average three farmers per day). If indeed there is excess water, additional farmers can also irrigate, otherwise they have to wait for their own turn or are given priority in the following week’s allocation. Once the week’s allocation schedule is ready, it is the responsibility of the farmers who have been allocated water to reconstruct the main furrow intake, clean the main canal leading to the micro-dam, operate the micro-dam and ensure that water transmission losses are minimised.

The weekly water allocation meetings can be very chaotic, and emotions can build. Scenes in which everybody stands up, and of women complaining bitterly about unfair treatment, are common. All eight meetings we attended between November 2007 and May 2008 demonstrated high emotion. On 27 May 2008, while undertaking spatial mapping in Manoo furrow, we heard the voices of women 3 km away at the water allocation venue. The women were complaining that the water committee was allowing some farmers to get a second irrigation turn, when they had not yet received their first. The women shouted for about 3 hours but, when the meeting ended, their voices were ignored. The following day, we found that some of these women had woken at 3 am and taken another farmer’s allocation to irrigate their plots. This resulted in quarrels the next morning which were later solved at a personal level, the women admitting guilt but refusing to compensate the offended person.

Furrows are often cleaned at the end of the Masika season in May to prepare for full irrigation during the dry season. Each farmer (member) is allocated a section to clean/repair (normally 17–20 wide steps) by the representatives. Cleaning the micro-dams is also undertaken jointly but the maintenance of tertiary canals is the responsibility of the members served by them. After repairing collapsed sections of the canals, there is less leakage along the furrow network. During our field work in May 2008 (i.e. at the end of the Masika season), desilting of the Mkanyeni micro-dam took 7 days, while cleaning the transmission canal took 2 weeks, with about 45 farmers (the majority of whom were men) being present each day. The group stated that 1 week is enough for canal cleaning unless interrupted by unforeseen social events (burials, weddings and NGO meetings were indeed frequent during the period February–June 2008).
In practice, participation in furrow maintenance activities and the irrigation requirements of one’s crops are not the only criteria to qualify for an irrigation turn. Farmers use other means to access water including, amongst others, utilising social relations with the furrow leaders (such as friendship and family ties), or using personal standing in the village (some of the vocal farmers were retired government civil servants, retired police officers and military officers). Farmers also share plots near the micro-dam with fellow farmers during times of extreme water shortage. A farmer upstream and near to the dam loans his/her plot or part of it to a friend downstream and, at the discretion of the downstream farmer, the plot owner may receive some gifts in return (e.g. salt or a portion of the harvest, a procedure known in Swahili as ‘zawardi’). We followed one farmer who shared some of his plots with others. This farmer is a descendant of one of the founding families and inherited a large land area from his father, who also inherited it from his father. The farmer is the elected representative of 35 farmers in the Ijeta zone, a position he has held for 4 years now. He is currently doing agri-business in another district and not able to farm all his land. He therefore delegated his zone representative role to another farmer, and shares most of his large land area with other farmers. He was subsequently re-elected as zone representative. The land-lending/gift system in this case seems to have been important for gaining and maintaining a leadership position.

Thus, the Mkanyeni case provides insight into the interaction between inequalities (e.g. access to land) and heterogeneity (e.g. differences in soils between the zones, farmers having many plots and kinship). The interaction configures power relations as seen in the attempt by founding families to maintain control over leadership roles by preselecting candidates for the chairperson’s position and in women’s continued exclusion in spite of their protests. The emergent power relation is constantly being contested and reinterpreted. While these collective arrangements seem to work for men, women are clearly disadvantaged. Dynamic interactions are also embedded within the wider biophysical and socio-economic context of the Makanya catchment. The water-sharing arrangement in Mkanyeni furrow influences and is also influenced by other furrows both in Bangalala village and further upstream (e.g. furrows in Vudee and Ndolwa villages). In the following section, we make the water use connection between Mkanyeni and three other furrows in Bangalala village and show how interdependencies emerge to counterbalance water asymmetry at this scale.

4.5. Water-sharing between furrows in Bangalala village

Currently four major furrows in Bangalala (namely Mghungani, Kinyanga, Manoo and Mkanyeni) use Vudee water for irrigation, domestic and livestock purposes. Mghungani and Kinyanga share one intake structure on the Vudee river before its confluence with the Ndolwa tributary and the section of the conveyance canal between the intake and the Kinyanga micro-dam (the distribution networks of the two furrows are not shown in Figure 4). Mkanyeni and Manoo only share the intake point, while minor furrows such as Mondo wangombe and Chungangwi are considered to be part of Manoo furrow (Figure 4).

Water allocation at the village level is first made by tributary. The other two (Manoo and Mkanyeni) abstract water downstream of the confluence but this water is considered to come from the Ndolwa tributary. This arrangement was arrived at based on the historical development of the furrow systems. Mghungani is said to be the oldest furrow in the village, followed by Manoo, then Mkanyeni and Kinyanga. Since Mghungani was already abstracting water from the Vudee tributary, Manoo furrow was allocated water from the Ndolwa tributary. It is further important to note that the intake structure
for Mghungani and Kinyanga is made of concrete and can only abstract about 50 l/s, leaving the excess water to flow downstream.

Water allocation between furrows sharing the same intake point is made on a rotational basis. For Mghungani and Kinyanga furrows, allocation is based on the estimated command area, with the former taking water for 5 days (since it is said to serve a bigger area) and the latter taking water for
2 days. However, weekly allocation for Manoo and Mkanyeni is based on a 4-3-3-4 system (i.e. in a week, one furrow abstracts water for 4 days and the other 3; the following week, the first furrow has 3 and the other has 4 days). The water allocation schedule between the Manoo and Mkanyeni also takes into account religious holidays. The furrow shares the inconvenience of working on a religious holiday by allowing one furrow to divert water on Friday (Muslim prayer day) and the other on Sunday (Christian prayer day), while the Saturday, which is the prayer day for Seventh Day Christians, alternates between the two furrows. According to the farmers, the schedule was designed by the village elders to avoid religious conflict.

The mapping of access to irrigated land in the Mkanyeni and Manoo furrow systems provides further insight to the water-sharing arrangements between the two furrows. The land map shows that most clans own land in both systems (Figure 5). Interestingly, no clan is dominant in both furrows. The table in Figure 5 shows that the Mnyone clan controls just over 3.3 ha in Mkanyeni and as much as 43 ha in neighbouring Manoo furrow; in contrast, the Mshana clan controls 33 ha in Mkanyeni and only 13 ha in Manoo. It is evident from the heterogeneous pattern of land ownership that any member of

![Fig. 5. Land control by major clans in Mkanyeni and Manoo furrow systems (Source: field notes).]
a clan controlling the largest share of irrigated land in one furrow cannot just ignore the interests of the other clans, as any selfish act may be reciprocated in another furrow where the clan is not dominant. Here inequality in access to land (in terms of some clans controlling more land than others) again combines with heterogeneity (farmers having plots in many furrows and multiple membership) to mitigate the negative impact of water asymmetry between furrows in Bangalala village.

5. Discussion and conclusions

This paper has aspired to provide a conceptual clarity to situations where collective action has emerged and has been sustained despite water asymmetry. We first studied internal arrangements with respect to water sharing within one canal organisation in Makanya catchment, Tanzania, and found a certain level of inequality of access to land (Gini coefficient of 0.58) and thus of access to water. This inequality might be understood as the outcome of underlying dynamics that limit excesses: if land and water become concentrated in too few hands, irrigators may opt out and shift their efforts to another canal, making the mobilisation of labour for maintenance more problematic, and hence possibly leading to system collapse. This hypothesis could be verified by measuring the inequality of access to land and water in many furrow systems, and by investigating any variation found in relation to the collective ability to share water and mobilise labour for maintenance.

But this inequality alone appears insufficient to explain how these canal organisations have been able to endure. We consider heterogeneity to be an additional factor that has led to mutual dependencies among the Bangalala village irrigators. First, there are systematic differences in soils in the upper and lower parts of the command areas of the canals, which not only leads to differences in water requirements and frequency of watering, but also to different crops being grown (e.g. vegetables and maize, in the upper and lower part of the command areas, respectively); irrigators need both, and can barter and trade. Second, water users along one canal have close kinship ties with other irrigators in the command area of the same canal, and in neighbouring canals. Third, upstream irrigators cannot completely ignore downstream counterparts, due to the large labour requirements needed to repair and maintain the river intake, the main canal and often also the storage tank. Fourth, many of the irrigators have plots in different parts of the command area, resulting in irrigators having multiple interests and loyalties, which inhibits unilateral action.

The interactions between water asymmetry, inequality and heterogeneity influence and configure power relations and hence the nature of water allocation. We observed that inequality in access to irrigated land also leads to disproportionate water allocation. It is farmers with larger land endowments, with many family members among the group of irrigators, and with good communication skills, who are able to secure access to more frequent water turns to irrigate their larger area or their several plots located in different zones. We observed in Mkanyeni’s Thursday water allocation meetings that farmers with more land tend to dominate the meetings and that decisions often go their way. Women tend to lose out, although they often resort to alternative ways to access water (e.g. ‘theft’, borrowing from neighbours, etc.). The larger landowners, who in most cases are members of furrow founding families, continue to maintain control by preselecting leaders of the canal organisation. They continue to influence furrow management to this day even when the government abolished clan-based water management in the 1970s. Apparently, this degree of inequality does not jeopardise the integrity of the system, an observation which supports the findings of Molinas (1998) and Bardhan & Dayton-Johnson (2002).
The transformation over time and the ‘irregularities’ of water property rights observed in Makanya catchment have to be discussed within the context of plural institutions, plural laws and contested ownership found in Tanzania. All water resources were first declared public property by the colonial powers as early as 1923. The Water Ordinance of 1948, chapter 257 (Tanganyika United Trust Territory, 1948), stipulated in its Section 4 that ‘the entire property in water within the Territory is hereby vested in the Governor, in trust for His Majesty as Administering Authority for Tanganyika…’ They also set the condition for the development of plural institutions by allowing areas under ‘natives’ to be governed by local customs and traditions and those areas declared crown land to be managed by state-led water laws. The independent government subsequently abolished certain customary practices and opened up (‘villagised’) access to irrigation water to all villagers. However, old practices and powers persist and, in Makanya, irrigation water has never become fully public. The exclusion, conditions of entry and opportunistic behaviour (entry fees, limiting women’s access, etc.) observed in the furrows show that irrigation water might better be considered a club good or toll good (cf. Buchanan, 1965). This can be explained by the fact that the infrastructure has a history, and that the process of hydraulic property creation (Coward, 1986) affects, and is affected by, power relations. Physical structures and social relationships thus co-evolve. Their specific combination as found locally is thus not accidental, and mediates water access and control in the catchment.

The findings presented in this paper are relevant to our understanding of the functioning of water institutions more generally in three ways. First, inequality among users is not naturally a deterrent to collective action, and may even be considered a resource that can help initiate and maintain the collective good. However, collective action may still mirror other inequalities, as is the case with gender. Second, mutual dependencies that exist between users and user groups in a water system may similarly be considered to be a vital resource, and making such dependencies explicit or even consciously increasing them helps to stimulate collective action. Third, the combination of inequality and interdependencies may give rise to emerging dynamics that can explain sustained collective action in situations of water asymmetry. This is exemplified by the fact that the canal organisations described have been functioning for several generations, and have not collapsed but instead are still functional.

The current findings are confined to relatively small spatial and social scales, involving irrigators from one village. In such situations there may be inhibitions to unilateral action due to social and peer pressure. Spatial and social proximity may thus be a necessary condition for collective action in water asymmetrical situations to emerge. At larger spatial scales and over greater distances, for example when considering catchment areas or river basins, this is likely to be different. The social relationships that could promote collective action in such larger spatial scales have hardly been studied but could include inter-village marriages, church groups, seasonal or longer-term migration patterns, pastoral movements, as well as formal representation in local and district and higher-level government. A better understanding of such relationships, their inequalities and heterogeneity, may help identify already existing incentives for collective action when need arises. Those characteristics could well be powerful complementary arrangements to formal, top-down established basin organisations. Research is therefore needed to describe phenomena of water asymmetry, inequality and heterogeneity at larger spatial scales, and to analyse under which circumstances they occur. Such research could then connect with studies that discuss the possibilities and constraints of issue linking at the transboundary scale (e.g. Fischhendler et al., 2004; Meijerink, 2008; Dombrowsky, 2010).
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